A Study for an Unmanned Aerial Vehicle carrying a radiation spectrometer networked to the new Athens Center active in Space Weather Events forecasting

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Abstract:

A proposal is presented for flying a light Unmanned Aerial Vehicle (UAV) carrying a Linear-Energy-Transfer (LET) radiation spectrometer and networked to the Athens Neutron Monitor Data Processing Center (ANMODAP), active in Space Weather Events (SWE) forecasting.

The ANMODAP receives data from a large number of remote neutron monitor (NM) stations, provided in real time over the Internet, together with satellite data.

Through this project, the ANMODAP forecasting capability will be increased with the collection of data by the LET radiation spectrometer on the UAV, at high atmospheric altitudes.

Introduction

Solar relativistic particles measured at Earth have an essential property of bringing information on solar and interplanetary conditions much earlier than low and mid energy solar particles. The early detection of an Earth-directed solar proton event by NMs offers an opportunity of preventive prognosis of dangerous particle fluxes and can provide an alert with a very low probability of a false alarm [1].

A data collection system, with the capability of getting data from a large number of widely dispersed NM stations, has been developed at the Athens cosmic ray station. Up to now twenty three stations are accessible online, together with GOES and ACE satellites data.

A long-range effort to study the complex dynamics of the atmospheric radiation field on a global scale has been initiated [2]. For this purpose a comprehensive database is being generated, using aircraft measurements made by a Low-Let Radiation Spectrometer (LoLRS), to enable a multivariable global mapping of the cosmic ray induced particle environment and of the LET spectra at aviation altitudes.

The use of a small and light UAV, flying at high altitudes and carrying on board a detector for monitoring radiation levels and additionally telecommunication transceivers, is greatly advantageous because of the opportunity their measurements will provide to determine the impact of GLEs on the atmospheric radiation environment, and the possibility to obtain a quantitative assessment of the induced changes.

The main benefit of the high altitude flights (inside and/or above the tropopause) is that the meteorological phenomena will be limited and that a radio-link, having as node an UAV, can be very effective, almost as it happens from a satellite, according to the International Telecommunication Union (ITU) [3], [4]. These flights can offer a wide range of telecommunication capability [5] and the UAV, acting as High Altitude Platform (HAP), may cover a footprint that will be extended in a diameter up to 1000Km.

UAV

The references on the technological structure of already tested UAV prototypes show continuous development in automation and improvements in the power consumption, with the use of solar cells as the new attractive powered technology.

Figure 1 shows the PATHFINDER, one of the earlier successful solar powered UAVs, on a test flight over the Hawaiian islands in the summer of 1997, where it reached a record altitude of 21.8 km (71500 ft) [Courtesy : NASA – AeroVironment].

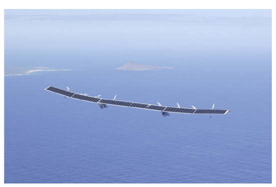


Fig. 1: Flight of "Pathfinder" UAV.

Environment and Instruments

The "Low-LET Radiation Spectrometer" (LoLRS) is a basic instrument that is designed to measure the energy deposited by particles with LET values from approximately 0.6 to about 14 keV/μm (electrons, protons, neutrons). The heart of the instrument is a silicon-lithium drifted diode 1 mm thick, with a sensitive area of 1 cm^2 [6].

A companion instrument, a "High-LET Radiation Spectrometer" (HiLRS), has been developed that measures energy deposited by heavy ions in microelectronic devices [7], causing Single Event Effects (SEEs). It operates on pulse height analysis principles and is designed for space and aviation applications.

On the other hand, it is known that Neutron Monitor detectors provide continuous ground based recording of the nucleonic component in the heliospheric secondary radiation that is related to primary cosmic rays. The worldwide network of neutron monitors is a powerful tool to allow measurements of the cosmic ray spectrum down to low primary energies using the Earth's magnetic field as a spectrometer. The neutron monitor energy range is complementary to the upper range of energies measured by cosmic ray detectors flown in space, Figure 2 [8].

With their high counting rates due to large detecting area that can only be accommodated at ground based stations, neutron monitors excel at measuring the small variations that occur in the galactic cosmic ray intensity at these high energies, especially when these variations are anisotropic [9] and are also vital for measuring the low fluxes of high energy particles accelerated in the vicinity of the Sun due to solar flares and coronal mass ejections.

Environment and Instruments (Cont.)

As the high energy particles from the most severe solar events, which can cause damage, arrive at Earth about **a half hour earlier** than the abundant 'killer' medium energy particles, they provide an opportunity to establish an early warning system to alert interested parties about the potential hazard to satellites, to the space station, to space personnel, and to aircraft flights scheduled over the poles.

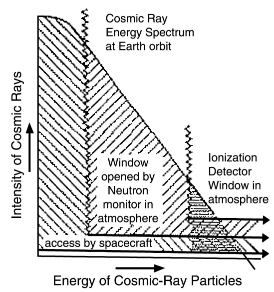


Fig. 2: Power spectrum of cosmic rays.

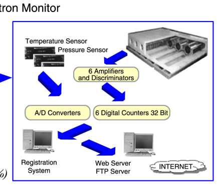
Taking into account that only few of the great number of solar flares and coronal mass ejections (CMEs) produce dangerous ion fluxes, it is not only critical to alert clients about the arrival of the most severe radiation storms, but also to minimize the number of false alarms against events which are not severe enough to cause damage or do not reach the Earth.

Figure 3 shows the effects from the interaction of the cosmic rays with the constituents of the Earth's atmosphere, producing a cascade of secondary particles, mostly energetic neutrons and protons [10].

Fig. 3: Cosmic ray progeny in the Earth's atmosphere.

In order to accomplish its mission, a fully functional data analysis Center in real time is in operation at the Athens Neutron Monitor Station (ANMODAP Center) for research applications (http://cosray.phys.uoa.gr), Figure 4. It has a vertical cut off rigidity of 8.53 GV. The system consists of six BF3 gas proportional counters with the enriched isotope B10 type BP28 Chalk River Canada.

Athens Neutron Monitor



$$
{}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{11}_{5}B \begin{cases} \rightarrow {}^{7}_{3}Li^{*} + {}^{4}_{2}a + Q_1 \ (94\%) \\ \rightarrow {}^{7}_{3}Li + {}^{4}_{2}a + Q_2 \ (6\%) \end{cases}
$$

Fig. 4: Athens Neutron monitor data collection system.

Measurements and Data

To perform a detailed study of potential cosmic ray variations and space weather conditions, it is necessary to compare good quality data from a number of high rigidity stations.

A multi-sided use of neutron monitors consisting of twenty three stations, operating in real-time, provides crucial information on space weather phenomena [11], [1]. In particular, the ANMODAP Center can give alert for the onset of ground level enhancements (GLEs) of solar cosmic rays which can be registered much earlier than the main part of the lower energy particles, that can be dangerous for causing damages on space-born and ground based electronic systems.

Moreover, the monitoring of the precursors of cosmic rays gives an advanced estimate on what kind of solar-terrestrial events should be expected, on geomagnetic storms and/or on Forbush Decreases.

In other words, the network of Neutron Monitors is a unified multidirectional spectrograph/detector characterized by considerable accuracy, providing a significant tool of forecasting the arrival of interplanetary disturbances at the Earth, Figure 5.

An example of a characteristic sequence of events is depicted in Figure 6, which shows data from seven different neutron monitor stations. At the point "A", a CME occurred on the sun. At "B", the CME arrives at Earth and cosmic rays decrease suddenly, generating a FD. At "C", a second CME occurred on the sun. This one accelerated high energy particles that reached the Earth minutes later, causing a GLE, that is, the sudden increase (spike) in neutrons received by the neutron monitors. At "D", the second CME arrives at Earth and cosmic rays decrease again: another FD.

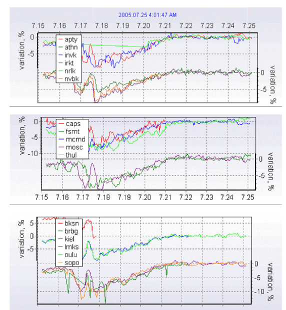


Fig. 5: NM plots from ANMODAP Center in July 2005.

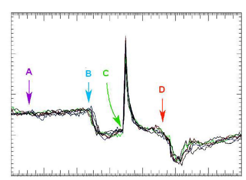


Fig. 6: Cosmic rays during high solar activity.

Conclusions

The collection of radiation data at different altitudes, in addition to ground based measurements, will be very important for estimation of the exposure level during extreme events of solar activity.

The flight of an unmanned vehicle at aviation altitudes carrying a radiation spectrometer, will generate the comprehensive database of the unified ANMODAP CENTER, which is based on the activities of the Athens and IZMIRAN cosmic ray groups and provides a real time monitoring of cosmic ray variations.

Thus, the joint complex analysis of the relevant information from space borne and ground based detectors will be completed with the on flight measurements, making possible a real time prediction of space weather phenomena that will minimize false alarms and will maximize the reliability and the timely forecasting of the arrival of dangerous fluxes from space.

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